VERSION 7.1
Mplus LANGUAGE ADDENDUM

In this addendum, changes introduced in Version 7.1 are described. They include corrections to minor problems that have been found since the release of Version 7 in September 2012 as well as the following new features:

- Multiple group factor analysis: A new method
- Multiple group factor analysis: Convenience features
- Exploratory factor analysis: Convenience features
- Mixture modeling: A 3-step modification
- Mixture modeling: A new distal outcome stepwise method
- New TECH4 output
- GROUPING and KNOWNCLASS convenience features
- DO option for MODEL TEST

MULTIPLE GROUP FACTOR ANALYSIS: A NEW METHOD

ALIGNMENT

The ALIGNMENT option of the ANALYSIS command is used with multiple group models to assess measurement invariance and compare factor means and variances across groups (Asparouhov & Muthén, 2013). It is most useful when there are many groups as seen in country comparisons of achievement like the Programme for International Student Assessment (PISA), the Trends in International Mathematics and Science Study (TIMSS), and the Progress in International Reading Literacy Study (PIRLS) as well as in cross-cultural studies like the International Social Survey Program (ISSP) and the European Social Survey (ESS). It is available when all variables are continuous with the ML, MLR, MLF, and BAYES estimators and for binary variables with the BAYES estimator. It is available for regular and Monte Carlo analyses using TYPE=MIXTURE and TYPE=COMPLEX

MIXTURE in conjunction with the KNOWNCLASS option for real data and the NGROUPS option for Monte Carlo analyses. The MODEL command can contain only BY statements for first-order factors where factor indicators do not load on more than one factor.

The alignment optimization method consists of three steps:

1. Analysis of a configural model with the same number of factors and same pattern of zero factor loadings in all groups.
2. Alignment optimization of the measurement parameters, factor loadings and intercepts/thresholds according to a simplicity criterion that favors few non-invariant measurement parameters.
3. Adjustment of the factor means and variances in line with the optimal alignment.

The ALIGNMENT option has two settings: FIXED and FREE. There is no default. In the FIXED setting, a factor mean is fixed at zero in the reference group. In the FREE setting, all factor means are estimated. FREE is the most general approach. FIXED is recommended when there is little factor loading non-invariance which may occur when there is a small number of groups. The ALIGNMENT option has two subsettings for specifying the reference group and the type of configural model used in the first step of the alignment optimization. The default for the reference group is the first group. The default for the type of configural model is CONFIGURAL. The alternative setting is BSEM where approximate invariance of measurement parameters is specified using Bayes priors (Muthén & Asparouhov, 2013). The subsettings are specified in parentheses following the FIXED or FREE settings. Following is an example of how to specify the ALIGNMENT option:

ALIGNMENT = FREE;

where the default reference group is group one when the GROUPING option is used and the last class when the KNOWNCLASS option is used. The default configural model is CONFIGURAL. Following are three equivalent ways to specify this:

ALIGNMENT = FREE (1 CONFIGURAL);

ALIGNMENT = FREE (1);

ALIGNMENT = FREE (CONFIGURAL);

The definition of the first group when the GROUPING option is used is the group with the lowest value on the grouping variable. The definition of the last class depends on the how the KNOWNCLASS option is specified. When the KNOWCLASS option specifies the group values, the reference group is the last value specified. When the KNOWNCLASS option gives only the grouping variable name, the reference group is the last grouping variable value found in the data set.

The ALIGNMENT option is used in conjunction with the SIMPLICITY, TOLERANCE, and METRIC options. The SIMPLICITY option is used to select the simplicity criterion of the alignment optimization. The simplicity function is optimized at a solution with a few large non-invariant parameters and many invariant parameters rather than many medium-sized non-invariant parameters. The SIMPLICITY option has two settings: SQRT and FOURTHRT. The SQRT setting takes the square root of the weighted component loss function. The FOURTHRT setting takes the double square root of the weighted component loss function. It may in some cases further reduce small significant differences. SQRT is the default. The TOLERANCE option is used to specify the simplicity tolerance value which must be positive. The default is 0.0001. The METRIC option is used to specify the factor variance metric. The METRIC option has two settings: REFGROUP and PRODUCT. REFGROUP is the default where the factor variance is fixed at one in the reference group. The

PRODUCT setting sets the product of the factor variances in all of the groups to one. The PRODUCT setting is not allowed with ALIGNMENT=FIXED.

Other options related to the ALIGNMENT option of the ANALYSIS command are the ASTARTS, ACONVERGENCE, and AITERATIONS options of the ANALYSIS command and the ALIGNMENT option of the OUTPUT command. The ASTARTS option is used to specify the number of random sets of starting values to use for the alignment optimization. The default is 30. The ACONVERGENCE option is used to specify the convergence criterion for the derivatives of the alignment optimization. The default is 0.001. The AITERATIONS option is used to specify the maximum number of iterations in the alignment optimization. The default is 5000. The ALIGNMENT option of the OUTPUT command can be used to show detailed measurement invariance test results for all items and factor mean comparisons for all pairs of groups.

MULTIPLE GROUP FACTOR ANALYSIS: CONVENIENCE FEATURES

MODEL

The MODEL option of the ANALYSIS command is used to automatically set up multiple group models for the purpose of testing for measurement invariance using the GROUPING option or the KNOWNCLASS option. It is available for CFA and ESEM models for continuous variables with the maximum likelihood and Bayes estimators; for censored variables with the weighted least squares and maximum likelihood estimators; for binary and ordered categorical (ordinal) variables using the weighted least squares, maximum likelihood, and Bayes estimators; and for count variables using the maximum likelihood estimator. It is not available for censored-inflated, count-inflated, nominal, continuous-time survival, negative binomial variables, or

combinations of variable types. The MODEL command can contain only BY statements for first-order factors. The metric for the factors can be set by fixing a factor loading to one in each group or by fixing the factor variance to one in one group. No partial measurement invariance is allowed.

The MODEL option has three settings: CONFIGURAL, METRIC, and SCALAR. These settings can be used alone to set up a particular model or together to test the models for measurement invariance. Chi-square difference testing is carried out automatically using scaling correction factors for MLM, MLR, and WLSM and using the DIFFTEST option for WLSMV and MLMV. The settings cannot be used together for ESTIMATOR=BAYES and for Monte Carlo analyses. Full analysis results are printed along with a summary of the difference testing. The CONFIGURAL setting produces a model with the same number of factors and the same set of zero factor loadings in all groups. The METRIC setting produces a model where factor loadings are held equal across groups. The SCALAR setting produces a model where factor loadings and intercepts/thresholds are held equal across groups. When the factor variance is fixed to one in one group, it is the first group when the GROUPING option is used and the last class when the KNOWNCLASS option is used.

The MODEL option for testing measurement invariance is specified as follows:

MODEL = CONFIGURAL METRIC SCALAR;

which specifies that configural, metric, and scalar models will be estimated and difference testing of the models will be done. Following is a detailed description of the parameter specifications obtained when using the CONFIGURAL, METRIC, and SCALAR options.

CONTINUOUS, CENSORED, AND COUNT VARIABLES

For continuous, censored, and count variables, the CONFIGURAL setting has factor loadings, intercepts, and residual variances free across groups and factor means fixed at zero in all groups. If the metric of a factor is set by fixing a factor loading to one, factor variances are free across groups. If the metric of a factor is set by freeing all factor loadings and fixing the factor variance to one, the factor variance is fixed at one in all groups.

The METRIC setting has factor loadings constrained to be equal across groups, intercepts and residual variances free across groups, and factor means fixed at zero in all groups. If the metric of a factor is set by fixing a factor loading to one, factor variances are free across groups. If the metric of a factor is set by freeing all factor loadings within a group and fixing the factor variance to one, the factor variance is fixed at one in one group and is free in the other groups.

The SCALAR setting has factor loadings and intercepts constrained to be equal across groups, residual variances free across groups, and factor means fixed at zero in one group and free in the other groups. If the metric of a factor is set by fixing a factor loading to one, factor variances are free across groups. If the metric of a factor is set by freeing all factor loadings within a group and fixing the factor variance to one, the factor variance is fixed at one in one group and is free in the other groups.

BINARY VARIABLES

The CONFIGURAL and SCALAR settings are allowed for binary variables. The METRIC setting is not allowed for weighted least squares because this model is not identified for binary variables due to scale factors or residual variances being allowed to vary across groups. The METRIC setting is allowed for maximum likelihood because residual variances are implicitly fixed at one in all groups as part of the model.

WEIGHTED LEAST SQUARES AND THE DELTA PARAMETERIZATION

For binary variables using weighted least squares estimation and the Delta parameterization, the CONFIGURAL setting has factor loadings and thresholds free across groups, scale factors fixed at one in all groups, and factor means fixed at zero in all groups. If the metric of a factor is set by fixing a factor loading to one, factor variances are free across groups. If the metric of a factor is set by freeing all factor loadings and fixing the factor variance to one, the factor variance is fixed at one in all groups.

The SCALAR setting has factor loadings and thresholds constrained to be equal across groups, scale factors fixed at one in one group and free in the other groups, and factor means fixed at zero in one group and free in the other groups. If the metric of a factor is set by fixing a factor loading to one, factor variances are free across groups. If the metric of a factor is set by freeing all factor loadings within a group and fixing the factor variance to one, the factor variance is fixed at one in one group and is free in the other groups.

WEIGHTED LEAST SQUARES AND THE THETA PARAMETERIZATION

For binary variables using weighted least squares estimation and the Theta parameterization, the CONFIGURAL setting has factor loadings and thresholds free across groups, residual variances fixed at one in all groups, and factor means fixed at zero in all groups. If the metric of a factor is set by fixing a factor loading to one, factor variances are free across groups. If the metric of a factor is set by freeing all factor loadings and fixing the factor variance to one, the factor variance is fixed at one in all groups.

The SCALAR setting has factor loadings and thresholds constrained to be equal across groups, residual variances fixed at one in one group and free in the other groups, and factor means fixed at zero in one group and free in the other groups. If the

metric of a factor is set by fixing a factor loading to one, factor variances are free across groups. If the metric of a factor is set by freeing all factor loadings within a group and fixing the factor variance to one, the factor variance is fixed at one in one group and is free in the other groups.

MAXIMUM LIKELIHOOD

For binary variables and maximum likelihood estimation, the CONFIGURAL setting has factor loadings and thresholds free across groups and factor means fixed at zero in all groups. If the metric of a factor is set by fixing a factor loading to one, factor variances are free across groups. If the metric of a factor is set by freeing all factor loadings and fixing the factor variance to one, the factor variance is fixed at one in all groups.

The METRIC setting has factor loadings constrained to be equal across groups, thresholds free across groups, and factor means fixed at zero in all groups. If the metric of a factor is set by fixing a factor loading to one, factor variances are free across groups. If the metric of a factor is set by freeing all factor loadings within a group and fixing the factor variance to one, the factor variance is fixed at one in one group and is free in the other groups.

The SCALAR setting has factor loadings and thresholds constrained to be equal across groups and factor means fixed at zero in one group and free in the other groups. If the metric of a factor is set by fixing a factor loading to one, factor variances are free across groups. If the metric of a factor is set by freeing all factor loadings within a group and fixing the factor variance to one, the factor variance is fixed at one in one group and is free in the other groups.

ORDERED CATEGORICAL (ORDINAL) VARIABLES

The METRIC setting is allowed for ordered categorical (ordinal) variables in some cases. When it is allowed, the metric of a factor must be set by fixing a factor loading to one. The METRIC setting

is not allowed for ordered categorical (ordinal) variables when a factor indicator loads on more than one factor, when the metric of the factors is set by fixing the factor variance to one, and when Exploratory Structural Equation Modeling (ESEM) is used.

WEIGHTED LEAST SQUARES AND THE DELTA PARAMETERIZATION

For ordered categorical (ordinal) variables using weighted least squares estimation and the Delta parameterization, the CONFIGURAL setting has factor loadings and thresholds free across groups, scale factors fixed at one in all groups, and factor means fixed at zero in all groups. If the metric of a factor is set by fixing a factor loading to one, factor variances are free across groups. If the metric of a factor is set by freeing all factor loadings and fixing the factor variance to one, the factor variance is fixed at one in all groups.

The METRIC setting has factor loadings constrained to be equal across groups, scale factors fixed at one in one group and free in the other groups, and factor means fixed at zero in one group and free in the other groups. The first threshold of each item is held equal across groups. The second threshold of the item that is used to set the metric of the factor is held equal across groups. Factor variances are free across groups. For a discussion of these specifications, see Millsap (2011).

The SCALAR setting has factor loadings and thresholds constrained to be equal across groups, scale factors fixed at one in one group and free in the other groups, and factor means fixed at zero in one group and free in the other groups. If the metric of a factor is set by fixing a factor loading to one, factor variances are free across groups. If the metric of a factor is set by freeing all factor loadings within a group and fixing the factor variance to one, the factor variance is fixed at one in one group and is free in the other groups.

WEIGHTED LEAST SQUARES AND THE THETA PARAMETERIZATION

For ordered categorical (ordinal) variables using weighted least squares estimation and the Theta parameterization, the CONFIGURAL setting has factor loadings and thresholds free across groups, residual variances fixed at one in all groups, and factor means fixed at zero in all groups. If the metric of a factor is set by fixing a factor loading to one, factor variances are free across groups. If the metric of a factor is set by freeing all factor loadings and fixing the factor variance to one, the factor variance is fixed at one in all groups.

The METRIC setting has factor loadings constrained to be equal across groups, residual variances fixed at one in one group and free in the other groups, and factor means fixed at zero in one group and free in the other groups. The first threshold of each item is held equal across groups. The second threshold of the item that is used to set the metric of the factor is held equal across groups. Factor variances are free across groups. For a discussion of these specifications, see Millsap (2011).

The SCALAR setting has factor loadings and thresholds constrained to be equal across groups, residual variances fixed at one in one group and free in the other groups, and factor means fixed at zero in one group and free in the other groups. If the metric of a factor is set by fixing a factor loading to one, factor variances are free across groups. If the metric of a factor is set by freeing all factor loadings within a group and fixing the factor variance to one, the factor variance is fixed at one in one group and is free in the other groups.

MAXIMUM LIKELIHOOD

For ordered categorical variables and maximum likelihood estimation, the CONFIGURAL setting has factor loadings and thresholds free across groups and factor means fixed at zero in all groups. If the metric of a factor is set by fixing a factor loading to

one, factor variances are free across groups. If the metric of a factor is set by freeing all factor loadings and fixing the factor variance to one, the factor variance is fixed at one in all groups.

The METRIC setting has factor loadings constrained to be equal across groups, thresholds free across groups, and factor means fixed at zero in all groups. If the metric of a factor is set by fixing a factor loading to one, factor variances are free across groups. If the metric of a factor is set by freeing all factor loadings within a group and fixing the factor variance to one, the factor variance is fixed at one in one group and is free in the other groups.

The SCALAR setting has factor loadings and thresholds constrained to be equal across groups and factor means fixed at zero in one group and free in the other groups. If the metric of a factor is set by fixing a factor loading to one, factor variances are free across groups. If the metric of a factor is set by freeing all factor loadings within a group and fixing the factor variance to one, the factor variance is fixed at one in one group and is free in the other groups.

EXPLORATORY FACTOR ANALYSIS: CONVENIENCE FEATURES

For exploratory factor analysis, chi-square difference testing of the number of factors is carried out automatically comparing m-1 factors to m factors. Chi-square difference testing is carried out automatically using scaling correction factors for MLM, MLR, and WLSM and using the DIFFTEST option for WLSMV and MLMV.

MIXTURE MODELING: A 3-STEP MODIFICATION

An error has been corrected in the R3STEP, DU3STEP, and DE3STEP options. This error results in only minor differences in the results.

With DU3STEP, and DE3STEP distal outcome analysis, a check has been added to make sure that Step 3 classification of subjects agrees with Step 1 classification of subjects.

There is a new version of Web Note 15 posted on the website.

MIXTURE MODELING: A NEW DISTAL OUTCOME STEPWISE METHOD

A new stepwise distal outcome method proposed by Lanza et al. (2013) has been added. The AUXILIARY option is used in conjunction with TYPE=MIXTURE with one categorical latent variable to identify continuous and categorical variables for which the equality of means or probabilities across latent classes will be tested using a stepwise approach. When more than one variable is given, each variable is tested separately. For continuous distal outcomes, the setting DCONTINUOUS in parentheses is placed behind the variables on the AUXILIARY statement for which equalities of means across latent classes will be tested. For categorical distal outcomes, the setting DCATEGORICAL in parentheses is placed behind the variables on the AUXILIARY statement for which equalities of probabilities across latent classes will be tested. The short form of these settings is DCON and DCAT. Following is an example of how to specify these settings:

AUXILIARY = drinks (DCONTINUOUS) depress (DCATEGORICAL);

where the equality of means for drinks and probabilities for depress will be separately tested across classes.

The list function can be used with these settings, for example,

AUXILIARY = y1-y4 (DCON) u1-u4 (DCAT);

When the list function cannot be used, the specification is:
AUXILIARY = (DCON) y1 y5 y7 y8;

NEW TECH4 OUTPUT

Standard errors and p-values are now available for the TECH4 estimates of latent variable means, variances, and covariances.

GROUPING AND KNOWNCLASS CONVENIENCE FEATURES

The GROUPING option can be specified by mentioning only the number of groups, for example,

GROUPING = country (34);

where country is the grouping variable and the number 34 specifies that there are 34 groups. The group values are taken from the data. The reference group is the group with the lowest value. Default group labels are used. G1 is the label for the group with the lowest value, g2 is the label for the group with the next value, etc.

The KNOWNCLASS option can be specified in conjunction with the CLASSES option by mentioning only the number of groups, for example,

CLASSES = c (34);

KNOWNCLASS = c (country);

where country is the grouping variable and the number 34 specifies that there are 34 groups. The group values are taken from the data. The reference group is the last value. Class labels use the KNOWNCLASS variable where %c#1% is the label for the group with the first value, %c#2% is the label for the second value, etc,. It is recommended that the data be sorted on the grouping variable prior to the analysis if this method is used. Then the reference group is the highest value and %c#1% is the label for the group with the lowest value, %c#2% is the label for the next value, etc,.

The NGROUPS option of the MONTECARLO command has been extended for use with TYPE=MIXTURE. It is used to specify the number of classes to be used for data generation and in the analysis. The program automatically assigns the label %g#1% to the first class, %g#2% to the second class, etc. These labels are used in the MODEL POPULATION and MODEL commands.

DO OPTION FOR MODEL TEST

The DO option is now available for MODEL TEST. The DO option provides a do loop to facilitate specifying a set of tests involving model parameters that will be jointly tested using the Wald test. Following is an example of how to specify a do loop:

```
MODEL:
y1 ON x1 (p1);
y1 ON x2 (p2);
y1 ON x3 (p3);
y2 ON x1 (q1);
y2 ON x2 (q2);
y2 ON x3 (q3);

MODEL TEST:
DO (1, 3) 0 = p# - q#;
```

where the numbers in parentheses give the range of values for the do loop. The number sign (#) is replaced by these values during the execution of the do loop. Following are the tests that are carried out based on the DO option specified above:

```
0 = p1 – q1;
0 = p2 – q2;
0 = p3 – q3;
```

REFERENCES

Asparouhov, T. & Muthén, B. (2013). Web Note 18.

Lanza, S.T., Tan, X, & Bray, B.C. (2013). Latent class analysis with distal outcomes: A flexible model-based approach. Structural Equation Modeling, 20, 1-26.

Millsap, R.E. (2011). Statistical approaches to measurement invariance. Taylor and Francis Group: New York.

Muthén, B. & Asparouhov, T. (2013). Web Note 17.